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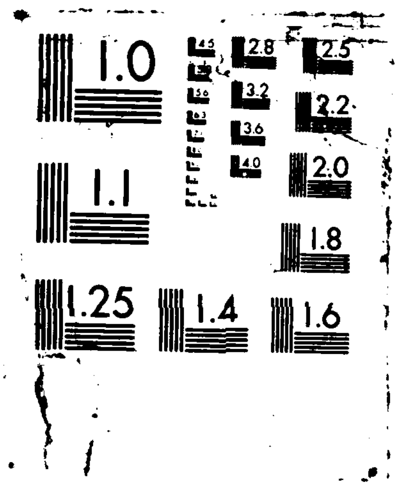
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AN INVESTIGATION OF FUNCTIONAL DEFICIENCIES IN TACTICAL AIRCRAFT MAINTENANCE FACILITIES

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics

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Frederick D. Keller, B.S.

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Frederick D. Keller

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Abstract

This thesis was based on the hypothesis that functional deficencies in aircraft maintenance facilities could be reduced if definitive floorplans and functional specifications were available. The thesis examined deficiencies in tactical aircraft maintenance facilities which affected the functional users. Problems with the military construction program were explored through the programming, design, and construction phases. Emphasis was placed on those defects which negatively impacted the functional user's ability to efficiently carry out aircraft maintenance operations.

Research consisted of observing 25 maintenance facilities, reviewing 28 facility project files, attendance at 30 facility design reviews, and review of pertinent literature. Those types of maintenance facilities which appeared frequently in the MCP were selected for research.

The objective of this thesis was to define a methodology to improve the functional utility of tactical aircraft maintenance facilities through improved design. The process involved identification of deficiencies and recommendations for corrective actions.

Conclusions from this research indicated most maintenance facilities were designed as one-of-a-kind projects with little benefit from construction of similar type facilities. The same types of mistakes were often repeated, or previously successful aspects of completed facilities were designed differently due to lack of definitive floorplans, criteria, and specifications. The author recommended an initiative to develop definitive prints and specifications, of bidding document quality, for frequently built aircraft maintenance facilities. Additionally, a recommended methodology to accomplish this task successfully was developed and outlined by the author.

AN INVESTIGATION OF FUNCTIONAL DEFICIENCIES IN TACTICAL AIRCRAFT MAINTENANCE FACILITIES

I. Introduction

General Issue

Every year millions of dollars are spent building or renovating tactical aircraft maintenance facilities. In Fiscal Year 1984 and 1985 major commands submitted total Air Force Military Construction Program (MCP) requirements of \$4.0 billion. Program Objective Memorandum (POM) submittal for 1984 was \$2.3 billion, including \$529 million for 127 logistics related projects. POM submittal in 1985 was \$2.6 billion and contained \$680 million for 153 logistics related projects including aircraft maintenance facilities (65:3). Professional base level Air Force (AF) engineers, major command engineers, the Army Corps of Engineers (COE), and civilian architectural and engineering firms are tasked with satisfying the needs of the user. For this purpose, the user is an aircraft maintenance technician or maintenance officer tasked with the additional duty of providing the correct scope, functional requirements, and special provisions to be included in a facility project book (24:33). As observed by the researcher, the user normally accomplishes

this task with no training, no knowledge of construction, and no experience in using the governing regulations. Most aircraft maintenance facilities have no definitive drawings; the products which attempt to achieve this end are dated, general, and deficient in functional utility (29). Occasionally the right combinations of talent come together to program, design, and construct an excellent facility. However, more often than not, facilities are functionally deficient, have limited flexibility, and do not comply with all governing regulations, specifications, and safety codes. The efficiency of the aircraft maintenance performed is often less than optimal due to factors such as poor shop layout, poor floor plans, malpositioned utilities, omission of mechanical, electrical, and civil requirements, access problems, or failure to incorporate state-of-the-art techniques and technologies (36:1).

Specific Problem

The lack of definitive drawings and functional specifications for tactical aircraft maintenance facilities may result in functionally deficient buildings. A methodology is needed through which definitive floorplans and functional specifications can be defined for tactical aircraft maintenance facilities.

Objective

The purpose of this study was to define a methodology to improve the functional utility of tactical aircraft maintenance facilities through improved design. The process of developing a methodology involved identification of deficiencies and recommendations for corrective actions.

Research Questions

The research issue will be examined in the tactical aircraft maintenance environment. Observation of thirty MCP facility design reviews, over a period of four years, significantly influenced selection of the following research questions:

1. What types of maintenance facilities are most frequently included in the MCP?

2. What are the responsibilities of the functional user in the MCP process?

3. Why doesn't the functional user identify all requirements in the facility project book?

4. What prevents all of the user's requirements from being satisfied?

5. How do functional deficiencies impact the aircraft maintenance activity?

6. Why do some deficiencies seem to keep recurring?

7. What is the impact of not having adequately defined floorplans and functional requirements?

8. Has there been any attempt to benefit from lessons-learned during design and construction of similar type facilities?

9. How can previously designed facilities be used to improve programmed facilities?

10. What methodology can be used to develop definitive drawings and functional specifications for maintenance facilities?

Assumptions and Limitations

This study was limited to unclassified tactical aircraft maintenance facilities used by the active duty AF in the United States (U.S.). Requirements for hardened or semi-hardened facilities were not considered. Hardening of facilities changes the structural and mechanical design, not the functional requirements inherent to the maintenance process. Selected facilities were observed first hand while others were analyzed from project files. Aircraft maintenance facility projects in Tactical Air Command (TAC) and Alaskan Air Command (AAC) formed the data base for the study. The projects researched supported F-15, A-10, and F-16 maintenance operations. Facility deficiencies were looked at from the perspective of the functional user. Detailed technical discussions were not included. However, recommendations to correct deficiencies were of sufficient detail to allow professional engineers or architects to understand the requirements. Discussions of the MCP exclude

the parts of the program which occur after project submission to the Headquarters United States Air Force Engineering and Services Office (USAF/LEE).

Background

Basic knowledge of the MCP is needed to understand the research problem. In July 1983, Major General Alfred G. Hansen, Deputy Chief of Staff for Logistics and Engineering (LEXP) stressed the importance of educating the people in the field on how the Program Objective Memorandum (POM) works and how to prioritize and articulate logistics requirements to the Major Command (MAJCOM) planners active in the POM process (65:1). The MCP sequence of events begins when a logistician, planner, or aircraft maintainer determines there is a need for a new facility, or a major renovation of a facility is required. The base level user of the proposed facility then initiates a Logistics Facility Summary data report. In September 1982 USAF/LEXP provided specific guidance and tasked all MAJCOMs to submit facility summaries for logistics projects in future years (65:1). The facility summaries are used by USAF/LEXP to support and defend projects when questioned by the Office of Secretary of Defense (OSD) and Congress (65:1). At base level the information from the facility summary should be used by the Civil Engineers (CE) to complete the MILITARY CONSTRUCTION PROJECT DATA Form (DD Form 1391). The intended user of the proposed facility provides the project description, the

current situation, and the impact if the facility is not provided. The base level programmer completes a rough estimate of the project cost based primarily on type of facility and square footage. Special requirements are priced separately and included, if identified by the functional user. The project then meets several boards, is prioritized, and depending on priority and support, may be forwarded to MAJCOM for inclusion in the command MCP. Projects ranked in the funded part (based on historical funding levels) of the MAJCOM MCP are forwarded to HQ USAF to compete with all other Air Force MCPs. Although project reviews do occur at MAJCOM headquarters, the scope and cost estimates of projects usually remain close to the original base level estimate. At this point the cost and scope of projects are very difficult to change. When funds for a project are appropriated the Air Force normally passes the project to the Army Corps of Engineers which contracts with an Architectural and Engineering (A-E) firm to do the design. At this point in the design process the A-E firm and the user are normally locked into a total cost and maximum size for the facility (24:1-60).

Justification

Every year the cost of satisfying the requirements for aircraft maintenance related facilities far exceeds the funds appropriated for that purpose. It is the responsibility of all government employees to conserve public funds.

Consequently, the objective of facility design is to satisfy the validated requirements of the user in an efficient manner (24:33). The after-the-fact correction of faulty designs, and modification of new facilities resulting from unmet user requirements, impose an unacceptable drain on AF resources and degrade overall capability.

Summary

The ultimate user of a proposed facility has many responsibilities in the programming and design process. Discussions with functional users of facilities studied indicate few aircraft maintainers are knowledgeable of the regulations which define their responsibilities and constrain facility scope (36). The hypothesis that functional deficiencies in aircraft maintenance facilities could be reduced if definitive floorplans and functional specifications were available, is addressed in Chapters IV and V. Few published sources specify design criteria for maintenance facilities. Those which are available leave a void between theory and execution. The research methodology in Chapter II guided development of a process to fill that void.

II. Methodology

Explanation of Research Methods

Direct observation of facilities and analysis of project files were the two primary types of research used to study the issue of functional deficiencies. Observations included visits to 25 maintenance facilities, attendance at 30 facility design reviews, and participation in Air Staff level program presentations. Analysis of project files included review of maintenance facility project files and published design criteria. Additional research included review of relevant literature, discussions with facility users, and discussions with MAJCOM and COE staff members. Few published sources addressed the issue of land based aircraft maintenance facility design. The primary sources of published facility design criteria were the documents produced by prime aircraft manufacturers under contract to the government. While the lack of published information on facility design was disheartening, historical data from using commands and accumulated experience in facility design provided an adequate data base. This effort was primarily qualitative and looked at designs for eight types of aircraft maintenance facilities.

Review of facility design criteria and specifications for Saudi Arabian aircraft maintenance facilities kept in perspective those design considerations which were driven

solely by limited funds. When Saudi facilities were built, cost was not a limiting factor (64:1.1-4.71).

The final product of this research was a sample matrix of functionally related facility deficiencies developed to link findings and recommendations (see Appendix B). The process by which the research questions were answered follows.

Using the TAC and AAC facility plans, several types of frequently built aircraft maintenance facilities were identified (52; 53). Thirty-six projects in various stages of programming, design, construction or in use were studied. Twenty-eight project files were reviewed and 25 of the facilities were physically observed. Table I summarizes the project types by base. Project books were reviewed to determine input of functional users in requirements determination. Review of programming actions and governing regulations provided answers as to why all requirements were sometimes not satisfied. On site observation of maintenance operations and discussions with functional users revealed numerous deficiencies impacting efficiency. Published TAC maintenance facility policy was examined (56). A logical and sequential combination of research information from maintenance facility projects was used to produce the methodology to adequately define definitive drawings and specifications for maintenance facilities.

Table I

Summary of Project Types by Base

Project Type	FY	Base	Reviewed Project File	Physically Observed Facility	Cost in Millions
AMU	84	Eielson	X	X	2.0
AMU	88	Elmendorf	X	X	1.0
AMU	86	Luke	X		.8
AMU	86	Moody	X		.8
AMU	*	Langley		X	.9
AMU	*	Langley		X	.9
AMU	*	Langley		X	.9
AMU	*	England		X	1.0
Engine Shop	85	Eielson	X	X	3.5
Engine Shop	87	Elmendorf	X	X	2.5
Engine Shop	88	Seymour	X		.7
Engine Shop	88	Nellis	X	X	3.8
Engine Shop	86	Luke	X		1.8
Engine Shop	89	Davis Mont.	X		2.2
Hush House	*	Elmendorf	X	X	1.5
Hush House	86	Elieson	X	X	2.2
Fuel Shop	88	Nellis	X		6.1
Fuel Shop	86	Luke	X		2.0
Fuel Shop	89	Cannon	X		3.0
Fuel Shop	**	Elmendorf	X	X	.7
Fuel Shop	*	Langley		X	3.0
Alert Shelter	90	Galena	X	X	10.0
Alert Shelter	*	King Salmon		X	10.0
Alert Shelter	89	Homestead	X		6.6
AGE Shop	*	Langley		X	1.5
AGE Shop	83	Eielson	X	X	2.8
AGE Shop	*	Elmendorf	X	X	2.0
Battery Shop	88	Elmendorf		X	1.5
Corrosion Shop	86	Eielson	X	X	9.0
Avionics Shop	85	Eielson	X	X	4.5
R&R Hangar	85	Eielson	X	X	2.5
Hangar	82	Eielson	X	X	2.8
Hangar	84	Eielson	X	X	8.0
Hangar	86	Eielson	X	X	3.5
Ramp Lighting	85	Nellis	X		.5
Maint Dock	87	Luke	X		6.3

* --Existing Facility

**--Modification, non-MCP

Summary

The basic approach of this research methodology was to look at several attempts to design and build similar maintenance facilities. If problems with existing facilities were documented, and the source of those deficiencies were identified a methodology could be developed to avoid repetition of defects. If successful designs were available, future efforts to build similar type facilities would logically produce more functionally correct facilities. Review of 28 project files and extensive observation of the design process provided the basis for findings and recommendations. However, observing maintenance operations presented the best cases for improvement opportunities.

III. Literature Review

Introduction

Literature relevant to the design of tactical aircraft maintenance facilities fell into three main areas: (1) general program management literature, (2) design criteria published by aircraft companies, and (3) design criteria used in actual USAF facility projects. To fully understand the design of tactical aircraft maintenance facilities all three areas were reviewed.

The program management concept is used by the COE and provides the basic structure for the design process. Each COE project is assigned a project manager (project and program are used interchangeably). Basic knowledge of project management is required to help identify the origin and cause of design deficiencies.

Facility design criteria developed by aircraft manufacturers are published and provided to the USAF through negotiated contracts. For this thesis, facility requirements plans from three contractors were reviewed. Each of the three provided requirements tailored to the specific aircraft which was being sold at the time.

In addition to the civilian safety, electrical, fire, and local building codes, design of AF facilities is subject to several AF manuals. Four of the most applicable were reviewed to provide understanding of (1) staff guidance,

(2) limitations, (3) criteria, and (4) management prerogative delegated to AF engineers.

Facility Design

Project Management. Program management has become an accepted management tool in the 1980s. The Army COE used the project management concept for facility design and construction and usually acted as the design and construction agent for the AF (29). To understand why facility deficiencies occur and to devise a methodology to prevent recurrence of those deficiencies an understanding of the project management (PM) process was mandatory.

Program management can be described as,

> The planning, scheduling, directing and controlling of company resources for a relatively short-term project which has been established for the completion of specific goals and objectives. Furthermore, project management utilizes the "systems approach" to management through the use of functionally controlled personnel (vertical hierarchy) assigned to a specific project (horizontal hierarchy) [59:2].

Twenty years ago program management was confined to construction companies and defense contractors. In the sixties and seventies the pace of the business world increased and changes in technology occurred daily. The growth of many companies and the accompanying bureaucracy highlighted the need for an organization internal to the parent company which was highly flexible, able to interact directly with clients, and direct resources necessary to

complete individual projects, on time and within budget. Growth of program management has occurred more out of necessity than through the active support of company executives. Program management's slow growth can be attributed to the lack of acceptance of management techniques necessary for success. The major problem areas centered around conflicts in authority and resources. Upper level managers had to relinquish some of their authority through delegation to the middle level program managers (60). Despite the resistance to change, program management has succeeded due to several driving forces. According to Galbraith, there are five reasons for its success:

1. The time span between project initiation and completion is increasing.

2. Capital committed to a project prior to use is increasing.

3. As technology increased, the commitment of time and money appeared to become inflexible.

4. Technology requires more and more specialized manpower.

5. Success requires more effective planning, scheduling, and controlling (45:90-107).

Galbraith's rationale for program management's success applies directly to AF MCPs. It requires approximately five years to proceed from project conception to occupancy of a facility. The cost of construction and the cost of the

weapon systems maintained in new facilities has increased as the technological sophistication of the aircraft increased. Just as Galbraith was an advocate of effective planning, scheduling, and controlling, Kerzner also stressed their importance in his project management books. Additionally, Kerzner discussed three problems common to project management which also occur in managing the MCP.

Bottlenecks in project management, communications with the client, and the effects of the horizontal hierarchy the project manager must operate in are discussed further. Bottlenecks in project management and communications with the client are related in that all communications must by design go through the project manager. Informal communication between the client's technical people and the contractor's technical people may occur, but all formal direction must come from the project manager. In the MCP there are normally two project managers (one AF and one COE) through which all communication must pass. Problems arise when the workload of one project manager (or both) is such that necessary information is not passed in a timely manner. Even when actions are executed quickly, the number of levels a simple request for a change must pass through and the repeated staffing take considerable time and tend to obfuscate the original request.

The horizontal hierarchy Kerzner writes about is the dependence a project manager has on his functional

counterparts to get his job done. The project manager must motivate his peers, witn no direct authority over them, to produce the results necessary for his project's success. If the COE project manager is unable to function well in his horizontal hierarchy the AF project suffers from benign neglect (59; 60).

Gaynor presented several thoughts concerning communication and the project manager. The importance of the communicator of the message is sometimes shortchanged. After all, he is the originator of the message. How he conveys the message, his confidence, and his command of the subject cause the communication process to succeed or fail (46:19). In large, bureaucratic, not-for-profit organizations, such as the AF, the role of the facility functional user in communicating his needs to the engineers is a critical link in the design process.

Review of the program management literature covered many criteria used to rate the effectiveness of a program manager. Cost, schedule, and performance were usually mentioned. Freidlob pointed out that cost control and budgeting were two of the primary scorecards used to grade program managers. He also indicated a project's success in terms of functional efficiency was hard to measure in a not-for-profit organization (39:61). This led the researcher to believe little external motivation existed to minimize functional deficiencies, and the measure of program

management success in the DOD was calculated using other parameters.

Kelley took a different approach to problems in program management and attempted to identify the characteristics of successful programs and program managers. This article was based on the book, In Search of Excellence, by Thomas J. Peters and Robert H. Waterman, Jr. Many of the attributes described in this book were applicable to the 12 successful defense acquisition programs studied (58:20). The article infers the following management styles or actions were found in successful programs:

1. A bias for action. The importance of making timely decisions cannot be overemphasized. If the program manager does not make the decision, others will make one for him and the results may be difficult to live with.

2. Stay close to the customer and remember, "works well in the field" is the most important factor as a measure of program success.

3. Good, open communications.

4. Productivity through people. You cannot do all the work yourself.

5. Stick to the knitting. You cannot be all things to all people.

6. Simultaneous loose-tight properties. Or in other words, the ability to produce on time, within budget,

following professional standards while operating in a mostly unpredictable environment with little supervision.

7. Experience as a program manager.

8. Ability to put a team together and lead it.

9. Ability to get along with people.

10. Willingness to accept responsibility and execute authority.

Successful program managers want to be program managers. Enthusiasm and interest were common to success. Most of these attributes must be worked at, but all are achievable.

Educating potential project managers was an issue drawing the attention of professionals in the field, as well as the academic world. Today's educational systems have not provided a universally accepted path to a career in project management. Debate continues as to whether a program manager should enter the field from a technical or a management background. Successful program managers have come from both types of educational backgrounds (70:11).

Because formal education for project managers was not available in the past (formal programs are still very limited), most program managers were not planning to be program managers--it just happened. The sink or swim approach was used when management had to react quickly to problems with an existing project or project management. Candidates usually were the top technical experts, a very experienced and well trained line manager, or a bright new

employee who did not have a current assignment. These quick fix approaches have been used often and obviously there needs to be a better way (70:11). Training for program managers was evolving slowly. Disagreement among program managers and disagreement about the academic curricula needed to train program managers was being examined. The type of training a project manager needed was dependent upon the type of projects encountered, e.g., high tech projects were more technically demanding, and low tech project management could be successfully handled with a strong management background. The author described in detail what program managers need to know, but said different types of projects required some special skills and skill levels. In the future, project managers will be trained through seminars or educated in formal degree programs. The formal academic training will eventually lead to professional status for the project manager (70:11).

The program manager literature implies that the project manager seems to be in a type of Demilitarized Zone (DMZ) between the engineering profession and management. Often the program manager has no one working for him full time. The success of a project depends on his ability to put together a good project team. Since a particular project is not the prime responsibility of the line manager, he is not going to easily give up his best people. Since most program managers have had no formal training in project management,

learning takes place through the "school of hard knocks." Success depends on the program manager's ability to lead and manage a small team of people on loan to him. Much of the work is done by technical specialists working for the line managers. The amount of backing senior management gives the program manager is sometimes in question because many of those managers have to relinquish some of their authority and resources to the program manager. The program manager is responsible for juggling many balls at the same time: cost, schedule, customer satisfaction, personnel management, technical problems, administrative duties, etc. Communication within the project management team, between the program manager and management, with the customer, and with the contractor are all very important. Outsiders cannot have much confidence in the project management team if they cannot find out what is going on. Supporting offices must be able to plan their work and the needs of the program manager must be identified in a timely manner. It is obvious project management is dynamic and demanding. Project managers must want to be project managers.

Aircraft Contractors. As stated previously, facilities designed for F-15, F-16, and A-10 aircraft were of primary interest. Consequently the facility requirements plans published by the respective aircraft manufacturers were reviewed.

F-15 Facility Requirements Plan. This plan defined facilities required to support F-15 weapon systems operations at USAF bases. The baseline data in the plan provided basic information to assist the AF in formulating F-15 systems facility support policies. The stated purpose of the plan was to "document the F-15 technical requirements for operational and maintenance support facilities which assists AF facility planners in evaluating existing and programmed facilities" (37:xiii). Technical descriptions are provided for each type maintenance facility. Since the information presented for each type of facility was similar in format, data from the Engine Inspection and Repair Shop sections were used to compare the information provided by the different contractors. McDonnell Aircraft Company logistics engineers stated there were no applicable definitive drawings for the shops in AFM 88-2, Definitive Designs of Air Force Structures (37:7-5-77). The recommended size for the shop was calculated using Table 8-3, in AFM 86-2, Standard Facility Requirements and contractor estimates of the number of scheduled and unscheduled engine removals. The functions of the facility were outlined, as were siting requirements, special construction and equipment installation requirements, electrical, and mechanical considerations. A suggested floorplan was provided showing administrative areas, work areas, and support equipment locations. Justification for the facility, functions to be performed in

the facility, and technical interface with installed support equipment (SE) were provided. The updated version of the McDonnell Aircraft Facility Requirements Plan is the most complete guide to facility design for the F-15.

F-16 Facilities Requirements and Design Criteria Report. This report defines the facilities required for support of the F-16 Weapons System at USAF bases. The report identified recommended structures, equipment layouts, and special requirements for F-16 operations, training, and maintenance. As with the F-15, this facilities plan provided definitive design information and referenced many AF publications and civilian codes which must be used by an A-E firm designing facilities (67). The engine inspection and repair shop, as described by General Dynamics (GD), was similar to the McDonnell Aircraft plan (37). Both contractors provided National Stock Numbers (NSNs) for support equipment, if available.

Fairchild Republic Company followed a format similar to the F-15 and F-16 facilities requirements reports. The formats of all the facility reports were determined by the aircraft System Program Office (SPO) at WPAFB, OH (57:xiv). The facilities included in this report were not peculiar to the A-10 and did not require concurrent development. The data was once again aimed at assisting government planners in assessing their present resources to determine the extent of compatibility with the A-10, and plan for modification of

existing or construction of new facilities. This plan and the two previous plans were all based on Multiple Command Regulation (MCR) 66-5, Combat Oriented Maintenance Organization and the current decentralized organizational structure used by Tactical Air Force (TAF) maintenance squadrons.

Saudi Arabian Aircraft Maintenance Facility Construction. The United States Government (USG), under contract with the Saudi Arabian government, provided complete facilities to support 60 F-15 aircraft with designs provided by A-E services. The COE served as the construction manager. The Air Force Logistics Command (AFLC) managed the facility program, consisting of more than 150 line items at five locations dispersed across Saudi Arabia (66:16). Aircraft maintenance facility construction was concentrated at Dhahran, Taif, and Kamis Mushayt (63:viii). The process of providing facilities to support the F-15 in Saudi paralleled the process used by the USAF to beddown aircraft at a new operating location. Facility site surveys were conducted with the objective of making maximum use of existing facilities. This objective was adhered to insofar as sound engineering, operational, and economic factors permitted (51:1-80). Results of the survey, based on actual on-site investigations and engineering analysis, were documented in the applicable facility report (50:1-1). Based on the site survey, the McDonnell Aircraft Company developed and published Facilities Design Criteria specifically for

F-15 maintenance facilities in Saudi (64). Not surprisingly, the format and content were similar to the F-15 Facility Requirements Plan for the F-15 used by the USAF (52).

Funding constraints which often limit the flexibility of designers working with USAF maintenance facilities were not a factor in designing the Saudi facilities (64:1-10). Photographs maintained by HQ AFLC Foreign Military Construction Division confirm that the interior and exterior architectural treatment of most Saudi facilities is superior in terms of materials and attractiveness to that of USAF maintenance facilities.

Since the research focused on functional deficiencies in maintenance facilities, available prints and specifications of the Saudi facilities were carefully reviewed (61). The Saudi facilities had floorplans similar to USAF maintenance facilities. The scope of individual facilities and square footage allocated to many functions were greater than that allowed under guidelines of AFM 86-2. Separate areas were dedicated to maintenance of installed and uninstalled aircraft engines. Additional space was provided for engine storage and for larger training rooms. Sun shelters were provided to protect aircraft from the intense sun (64:2-1-2-4). Light intensities in some maintenance areas were higher than in typical USAF facilities (64:2-28). The general level of detail in the Saudi Facility Design

Criteria exceeded that of the USAF plans. Physical observation of the Saudi facilities would have been ideal, but was not possible.

Contracted Studies. A concept study brochure on general purpose aircraft maintenance shops accomplished by the US Army Facilities Components System (AFCS) was reviewed. The stated purposes of the study were as follow: (1) to provide only sufficient design and shop layout to determine if the shop meets minimum functional requirements, (2) to provide an adaptable and rapidly constructed design for short term use, and (3) to provide designs not intended for use in normal construction, but for use in national emergencies.

While the stated purpose of this brochure did not apply directly to this thesis, the process by which the AFCS gathered the data and compared requirements for different types of fighters was useful in developing a methodology to achieve the objective of the thesis. AFCS personnel researched all available data for different types of fighter aircraft. A comparison chart showing recommended scope and shop equipment layout was then developed to support all fighter aircraft (28). This study was the only one available to the researcher where an attempt was made to develop a generic type maintenance facility capable of supporting most fighter and attack type aircraft. Although the level of detail and purpose made the results of this study

unusable in reducing functional deficiencies in U.S.-based permanent type facilities, the methodology could be used.

USAF Regulations. The following USAF regulations were used frequently, and impact facility design considerably. Understanding of the regulations was essential in designing functionally efficient and safe maintenance facilities. Only a brief explanation of each is provided.

AFM 86-1, Programming Civil Engineer Resources Appropriated Fund Resources. This manual explains the process which must be followed to initiate repair and construction projects. It explains the required documents and their preparation for Unspecified Minor Construction and Maintenance and Repair projects. The annual MCP submission is outlined and the responsibilities of the functional user are defined (24). Functional users of facilities can often benefit from major repair projects, including a modest level of minor construction, without undertaking the lengthy MCP route.

AFM 86-2, Standard Facility Requirements. This manual contains approved criteria for the type, number, and size of facilities AF units can use to support their missions. The manual also describes responsibilities, policies, and procedures for the facility requirements system. Specifically, the manual limits the scope of facilities and the functions to be conducted therein by assignment of a category group to the project. For example, if a unit

builds a drive-through hangar (category group 211-111), by definition, aircraft maintenance, inspection, and repair may be conducted within. Refueling, however, would be prohibited because the category group was not that of an alert shelter. Limitations on the size of aircraft maintenance facilities are contained in AFM 86-2. The 8,000 sq. ft. standard for a tactical AF AMU was just one example. Functional users of maintenance facilities must be aware of and understand the provisions of AFM 86-2 if they are involved in programming new facility construction or renovating older facilities (26).

AFM 88-2, Definitive Designs of Air Force Structures. This manual contains architectural definitive drawings that were used as guides in planning, programming, and designing AF structures. The manual is not current as an AF publication. However, the objective of the manual was sound and the potential benefits substantial (23:1).

> The availability of approved definitive drawings expedites the construction programming process by eliminating the delays and errors caused by the lack of firm design and requirements criteria. The use of definitive drawings leads to the development of standard working drawings and the use of site adaptation processes. This produces substantial savings in design and construction costs [23:1].

AFM 88-15, Definitive Designs of Air Force Structures. This manual contains construction criteria and standards applicable to structures and utilities at AF installations. The manual provides basic guidance for the

construction and selection of materials for permanent AF facilities. The manual restricts the options available to the functional user of a facility by defining compatible facilities, types of materials to be used in hazardous areas, and design limitations (22).

AFM 88-31, Selecting Architect-Engineer (A-E) Firms for Professional Services by Negotiated Contract. This manual describes the required process AF organizations must follow to select A-E firms providing professional services for military construction. It is consistent with the Federal Acquisition Regulation (FAR) and the Department of Defense (DOD) and Air Force FAR Supplements. It establishes a statutory fee ceiling for most design work associated with routine MCPs. Part of the selection process is the determination of qualified A-E firms for designing a particular project. The qualifications and experience of an A-E firm are of critical importance to the functional user of a facility. The quality and functional efficiency of the completed facility depend on the performance of the A-E.

Tactical Aircraft Maintenance Facility Construction

The TAC published the TAC NEW LOOK PLAN in September, 1978. The plan initiated a project to improve the work environment and incentives of maintenance people. The goals were as follow:

1. To upgrade maintenance facilities and furnishings.
2. To give recognition for outstanding performance.

3. To insure maximum support of the maintenance work force.

The goals were based on the fact that TAC aircraft maintenance people are the front line support people maintaining TAC's readiness. Their jobs require working outdoors in all types of weather, shift work, and weekend duty. NEW LOOK was intended to provide them with adequate facilities and support to compensate for these job requirements (54:1).

Headquarters TAC Engineering and Services also published a letter outlining special requirements and guidance to be used in designing new facilities. The letter included guidance on: (1) interior finishes, (2) wall treatments, (3) finishes, (4) comprehensive interior design, and (5) overall design (56). While the TAC letter may have reduced the number of unacceptable initial facility designs, the guidance did little to eliminate functional deficiencies in maintenance facilities.

Summary

Review of the available literature concerning design and construction of aircraft maintenance facilities revealed no information sponsored or published by the AF logistics community. In fact, the Logistics Facilities Board which usually meets once a year is the only formal logistics facility organization chartered with promoting logistics facility needs (65).

The logistics facility requirements plans published by aircraft manufacturers provided good basic guidance but in most cases were not available to facility managers (36). An understanding of project management and its application to the design process used by the COE is essential if one is to influence design decisions.

IV. Functional Deficiencies in Maintenance Facilities

Introduction

Aircraft maintenance facilities were categorized into eight types for the purpose of deficiency identification and analysis. As stated in the thesis methodology, a combination of three methods was used to identify facility deficiencies and deficiencies in the programming, design, and construction process.

The first method was observation of the programming, design, and construction process. Over a period of five years I was responsible for all aircraft related facility projects in the AAC. Working at the MAJCOM level, with frequent Air Staff interaction, I observed the AAC MCP process with its problems and deficiencies, and the programs of the other MAJCOMs as presented to the Air Staff.

The second method was a review of 28 aircraft maintenance facility project files in the AAC and TAC. Most USAF MCPs were initiated and followed a specific process outlined in AFR 86-1. The base level functional user would determine the need for a new facility, fill out a logistics facility summary, and provide inputs to the base civil engineers. A project book would be developed and sent to the appropriate headquarters with a DD Form 1391 (Military Construction Project Data). From that point on all available documentation on a specific facility project was usually maintained

in a project file, a copy of which was located at the applicable MAJCOM headquarters. Information in aircraft maintenance facility project files at HQ AAC and HQ TAC was reviewed. The specific projects reviewed are listed in Table I. Early in the review process, it was noted that similar type facilities had similar problems during design and construction. Comments concerning the project files reviewed apply to a given type facility, not a specific project.

The third method was to physically observe 26 maintenance facilities. Some facilities were observed under construction and later while in use. Others were only observed while under construction or in use. Conversations with the functional users of the facilities provided insight of deficiencies not readily visible through observation alone.

Aircraft Maintenance Units (AMUs)

An AMU consists of the technicians, managers, administrators, equipment and the facility necessary to operate and maintain a squadron (24) of tactical aircraft on a day-to-day basis (21). The size of the facility is limited to 8000 sq. ft. (26). The AMU was the most frequently built and renovated maintenance facility studied (20; 53). Approximately 246 people are assigned to an AMU (12:52-57). The functions which take place in the facility include administration, dispatch, tool storage and issue, supply, mobility, training, scheduling, documentation, technical order

maintenance, debriefing, and engineering and technical services (ETS). General problems encountered in design and construction of AMUs are documented in the following paragraphs, specific problems are in Appendix B.

The two most common functional deficiencies which impacted maintenance operations in the AMUs were size and functional layout of the facility. Size was documented as a deficiency in all project files and was commented on by users during all facility visits. Lack of space in the tool issue and support equipment storage section was the area most effected by the 8000 sq. ft. scope limitation. Lack of space for personal lockers, vending machines, and mobility equipment was common to all AMUs. Each functional user seemed to prefer a variation of the TAC approved definitive floorplan. In an attempt to improve the functional layout of an AMU, the architectural branch of HQ TAC Engineering Division published a single line drawing showing a recommended AMU floorplan (55). Unfortunately the floorplan had not been refined to a point where it satisfied all users, and the guidance for its use was misunderstood. Producing an optimal design for an AMU which would be supported by the engineers and aircraft maintainers takes considerable time, effort, and money. When confronted with a challenge to the AMU floorplan requiring immediate action the headquarters staff did the only expedient thing they could: waive the use of the floorplan (71).

Other major problems in the AMU are discussed here. The major problems and those of lesser importance are documented in Appendix B. Floor coverings were a problem in all AMUs. Many manhours were expended cleaning and waxing vinyl flooring. Sheet vinyl was too soft to withstand the heavy use in many parts of the AMUs. Wall coverings were sometimes not appropriate. The use of painted drywall proved to be a poor choice, because marks on the walls and dents made frequent repair and painting necessary. High use doors were not designed to withstand constant use in six AMUs. No provisions were made for storage and disposal of waste lubricants and fuel in any of the AMUs. Adequate provisions were often not made to accommodate the number of computer terminals required by the maintenance organization. All six of the AMUs which were physically observed had self-help projects under way. This included those AMUs which were newly constructed.

The new AMU at Langley AFB was constructed adjacent to the new Operations facility, and thus had access to a large briefing room for mass meetings. The AMU at Eielson AFB was constructed adjacent to a hanger, which could accommodate mass briefings. Other AMUs did not have the capability to hold mass briefings.

Engine Shops

Construction and renovation of engine shops followed the AMU in frequency of occurrence. All engine shop

projects reviewed were responsible for the complete teardown and reassembly of entire jet engines. Functions supported included intermediate maintenance, supply, parts cleaning, small gas engine repair, training, technical representatives, tool issue, administration, Support Equipment (SE) and War Readiness Material (WRM) storage. According to the project files reviewed, the most common problems affecting the functional user were as follow:

1. The floorplans for all of the fighter engine shops contained most of the same basic functions with proportionately the same amount of space dedicated to each function. As with the AMU, the desires of the particular user determined the outcome of the project. Through questioning each of the functional users charged with managing facility projects, it was learned that none had managed similar projects before, nor were familiar with the MCP manuals and regulations. This lack of experience led to repetition of many of the same mistakes in different engine shops.

2. Problems with bridge-crane systems were documented during design or use in five of the six engine shops studied. The basic requirements and specifications for the cranes were included in all of the facility plans published by the aircraft contractors (37:7-113; 67:7-268). Even with this guidance cranes were installed with insufficient numbers of hoists or one bridge instead of two. Some common initial operating problems were routing of electrical

controls, overheating of electrical components due to their location near overhead lighting, and travel speed of the hoists.

3. Each of the engine shops required a bearing and parts cleaning room. The design of the rooms and specifications for the engine parts cleaning equipment consumed considerable time and effort as evidenced by documentation in the project files. The type of cleaning vats and the size and specification for explosion proof electrical or hydraulic motors were not agreed upon.

4. The type of sealer or concrete floor topping used on the shop floor caused the users problems in three of the shops researched. The other three were not complete. According to the users and maintenance managers questioned, an engine shop is viewed as a high tech industrial area which is required to be attractive and clean. To achieve the desired effect many types of concrete sealers, paints, and floor coverings were tried--with poor results. The shop at Eielson AFB included an integral, colored, floor topping. The workmanship in applying the topping was poor, but the shop was not yet complete so no conclusions could be drawn about the effectiveness of the topping.

5. Lack of space in the tool issue and support sections of four shops was documented. A change to AFM 86-2 attempted to correct this deficiency (26:8-3).

Fuel Shops

The fuel systems shop is responsible for repair, functional check, and inspection of aircraft fuel and in-flight refueling systems. The shop also maintains external aircraft fuel tanks.

The seven most critical deficiencies in fuel cell design were the following:

1. Installation of deficient ventilation systems was most common. Ventilation serves two purposes in fuel shops. One system is required to provide fresh air for in-tank maintenance and another to keep the level of fuel vapor in the shop area below established levels. Problems with in-tank ventilation systems included the following: (1) the air ducts were not grounded, (2) the temperature of the air was too hot or too cold to allow the technician to work in the tank, and (3) the volume was insufficient to purge the tank in a timely manner. Two problems with shop ventilation were exchange of stratified vapor laden air near the shop floor and heating of make-up air required in northern tier shops. Four out of five shops had ventilation problems.

2. Improper treatment of electrical systems installed in hazardous areas. Three of the fuel shops studied were deficient in both ventilation and electrical systems.

3. Locating and interpreting all manuals and codes pertaining to installation of electrical systems was a major problem for all A-E firms.

4. Determining the hazardous classification of different areas in the facility and specifying the correct type electrical equipment consumed many hours. Additionally, hazardous areas in certain facilities were dependent on the type of aircraft maintained. The type of electrical equipment required is dependent on its distance from the fuel storage and transfer systems in the hangared aircraft undergoing maintenance. Therefore, location of internal and external fuel tanks as well as fuel vents dictate the class and division of electrical equipment. Few of the maintenance facilities studied met all electrical, fire, and safety requirements.

5. Many different proposed solutions to the problem of containing hazardous wastes were discussed. How to collect spilled fuel was the main problem. Installation of holding tanks, fuel/water separators, and leach fields were discussed without arriving at a consensus.

6. Contiguous grounding systems were required but seldom found.

7. Maintenance of comfortable working temperatures affected safety and efficiency in all fuel shops (40; 41; 42; 43; 44).

Hush Houses

A hush house is an air cooled sound compressor designed to test aircraft engines. The test cell function is responsible for testing engines to evaluate the quality of

maintenance and engine performance. Technicians troubleshoot engines, do minor maintenance, and make adjustments to installed and uninstalled aircraft engines. The Hush House is real property installed equipment (RPIE) and not real property, as normal facilities are. Because the AF was going to install many like facilities, an A-E firm was hired to develop standardized prints and specifications for installation of a complicated foundation. A pre-engineered, standardized steel building is then erected on the foundation. This method of design was intended to save money, speed erection, and improve the quality of facilities.

Major problems with all hush houses were as follow:

1. Expansion and contraction of exhaust tube liner panels due to the difference between ambient temperature and the temperature of the engine exhaust caused the liner panel to buckle, warp, and come loose.

2. No provisions were made to maintain suitable working temperatures for technicians in northern tier facilities. Because of the building's design and its function, the interior temperature was usually below ambient temperature.

3. No provisions were made for administrative space. Users had to erect portable or temporary shelters nearby and submit work orders for permanent structures.

4. Approval to refuel aircraft in the hush house was not granted unless extraordinary procedures were followed.

5. Entrance door track heating was inoperative and microswitches for door operation were unreliable (71; 72).

Alert Shelters

Alert shelters are required to house the alert force. The alert force provides the support required for the immediate launch of tactical aircraft for air defense missions. The branch is responsible for alert preflight inspections, servicing, towing, parking, minor maintenance, combat turns, and launch and recovery of alert aircraft (21:10-1).

The main problems with alert facilities are as follow:

1. The lack of space required to comply with all munitions quantity-distance safety requirements generated requests for waivers at all three alert facilities.

2. The inefficient alert cell heating systems resulted in stratification of hot and cold air in two northern tier facilities.

3. The outside air infiltrated around hangar doors due to poor seal design or poor maintenance.

4. The electrical systems did not meet established standards for hazardous areas.

5. The static grounds were not positioned correctly for aircraft and refueling equipment.

6. The aircraft parking plans were not designed to accommodate hot refueling of aircraft.

7. Two facilities lacked sufficient space for aircraft support equipment and spare parts.

8. The alert crews had to exit the building and reenter to board alert aircraft in one alert facility. This occurred because there was no direct interior access to alert aircraft due to lack of space.

9. The emergency lighting required in the cells was not installed in two facilities.

10. The electro-mechanical intrusion detection alarms used to secure alert aircraft cell did not work properly in two facilities.

Aerospace Ground Equipment (AGE) Shops

The AGE Branch is responsible for providing powered and nonpowered support equipment for the wing mission. Powered and nonpowered AGE is portable equipment used by technicians to aid in the repair of aircraft subsystems. The branch provides the capability for pickup, delivery, repair, modification, inspection and servicing of most AGE. The AGE facility provides space for maintenance and cleaning of equipment, parts storage, administration and mobility operations. Major problems with three AGE facilities are as follow:

1. Floor coverings were deficient. Paint peeled quickly, and concrete sealers deteriorated rapidly in all three shops. The sealers observed had no light reflective properties and did not improve the appearance of the work areas.

2. Space was not provided in two shops to store AGE which required protection during winter months of the work areas.

3. An equipment run-up room was designed improperly. Equipment viewing windows were not installed, cable access holes were not placed properly, and exhaust stack flues did not function properly.

4. Adequate ventilation was not provided to maintain carbon monoxide levels below established standards during winter months when shop doors were closed (three shops).

5. Industrial type sinks were not provided to handle personal hygiene requirements during shift changes (three shops).

6. Hot air curtains or remote control garage door type openers were not provided for efficient movement of equipment into and out of the shop (three shops).

7. Equipment had to be backed onto wash racks. A drive through equipment washing area would have been much more efficient (two shops).

8. Lubricant dispensing equipment to support frequent servicing operations was not installed. Manual servicing from cans and drums was the norm (three shops).

9. No provisions were made for the segregation and storage of waste fuel and lubricants (1; 2; 3).

Aircraft Hangars

Aircraft hangars provide protection for aircraft and a suitable working environment for technicians. Inspection, major maintenance, and modification of aircraft are accomplished inside of the protective structures. Many types of hangars exist and include facilities with huge expansive open bays or facilities with individual cells for each aircraft. Major problems with aircraft hangars were as follow:

1. Concrete floor sealers rapidly deteriorated. The sealers used had no light reflective properties and did not provide the proper appearance.

2. Expansion joints in concrete were not properly filled and provided areas for accumulating debris.

3. Trench drains were connected between cells providing a possible path for fuel vapor to travel. The trenches were not wide enough to allow for easy cleaning.

4. Some hangars had no provisions for segregation and disposal of waste fuel and lubricants.

5. The speed of the emergency manual mode of hangar door operation was far too slow to permit rapid evacuation of aircraft equipment from hangars.

6. Stratification of hot and cold air was a problem at bases during the winter season. Temporary canvas ducting had to be added to direct hot air to floor level.

7. One piece overhead hangar doors were designed improperly. The resulting unsafe condition led to the shut-down of an entire facility.

8. Uncommanded activation of fire detection and suppression systems charged an otherwise dry pipe system. Operations involving open hangar doors during winter months hadto be suspended until the system could be purged of water.

9. Special directions as to hangar lighting intensity had to be issued by the AF. Possible problems existed with using the Illuminating Engineering Society (IES) lighting standards.

10. Roof drainage was directed across aircraft ramp used by taxiing aircraft. Ice build-up in winter months was hazardous (47; 48; 49; 62; 69).

Miscellaneous Facilities

Miscellaneous facilities include battery shops, avionics shops, corrosion shops, and ramp lighting projects (16; 17; 19; 63). Investigation of these type facilities was not as intensive as that of previously discussed facilities. While problems existed in these facilities, few functional deficiencies were documented. Those problems documented include the following:

1. Ventilation in the portion of the battery shop dedicated to charging lead acid batteries was deficient.

2. Space for refrigeration of nickle cadmium batteries was inadequate.

3. No overhead hoist was available to handle large tractor batteries.

4. No efficient means of delivering or picking up batteries was in use. All batteries had to be carried in and out of the facility by hand or the delivery vehicle had to back inside the building.

5. The walls and benches in corrosive areas of the shop were not made of corrosion resistant materials.

6. The lack of airflow moving past the painter in corrosion control shops violated the Occupational Safety and Health Administration (OSHA) standards.

7. The orientation and placement of the aircraft to be painted was changed several times during design of the corrosion facility.

8. The criteria was vague and hard to find which identified the provisions necessary to design the capability to decontaminate aircraft.

9. Much of the equipment required by the functional user in the corrosion facility had to be identified, researched, and specified by the user. The design agent seemed to be unwilling or incapable of completing the work. Inexperience in designing aircraft related facilities seemed to be the cause of the problem.

10. Floorplan design of the avionics shop was the facilities major problem. Conversion from the traditional, conventional avionics shop layout to the more open floorplan of an integrated avionics shop was a lengthy and involved process.

11. The electrical power supplies and riser locations in avionics shops seemed to accommodate only one type of test station.

12. No standard seemed to exist for type of lighting fixtures to be used for airfield lighting. Changes in design criteria led to cancellation of a project.

Summary

Many examples of deficiencies in tactical aircraft maintenance facilities which affected the functional users' ability to perform in an efficient manner have been identified. As the facility programming, design, and construction process was examined, many of the deficiencies were encountered more than once. Discussions with the users and facility managers indicated that as the deficiencies became apparent work orders were submitted to correct the deficiencies. Some problems were not easily correctable. The resultant drain on productivity would continue until major modifications were accomplished years later. The cost of correcting the deficiencies identified was not calculated. However, the cost would seem to be substantial and room for improvement obvious.

V. Findings

Introduction

Chapter V continues the theme of discussing functional deficiencies established in the previous chapter. The emphasis is shifted from specific problems with individual facilities to more general findings. Findings related to the research questions identified in Chapter I are addressed first. Each of the ten questions is answered as completely as possible based on the results of the research conducted. Findings related to administrative problems and the MCP process itself are then discussed next.

Findings Related To Research Questions

Research Question #1. The Aircraft Maintenance Unit, Engine Shop, and Fuel Shop were three of the most frequently programmed and constructed maintenance facilities in TAC and AAC during the years 1984 to 1990 (52; 53). Table 1 shows the facility projects which the author researched and the approximate cost of each. As the frequency of construction for a certain type facility increases, the greater becomes the potential benefit of definitive floorplans and specifications. As evidenced by the standardized AF hush house foundation prints and pre-engineered structures, the quality, cost, and timeliness of construction surpasses that of typical MCPs (71; 72). Attendance at over 30 facility

design reviews revealed the tremendous number of manhours required by the COE to review prints and specifications prepared by civilian A-E firms. Of all the projects reviewed, no two similar facilities were designed by the same A-E firm. Essentially, all projects received one-of-a-kind treatment. Consequently, many of the same problems recurred had to be solved repeatedly. Those problems which were not recognized or solved correctly contributed to the number of design deficiencies.

Research Question #2. The responsibilities of the functional user in the MCP process were outlined in AFR 86-1 and passed to MAJCOMs through the logistics facility board chaired by the Chief, Logistics Facilities Programming Office. Review of project files and observation of over 30 facility projects and design reviews indicate few, if any, of the maintenance technicians or officers involved in the process understand their responsibilities. When an aircraft engine technician was tasked to provide detailed criteria and special facility requirements to an A-E firm whose engineers had never seen an engine test cell, experienced low frequency engine vibration, or understood cell depression, the potential for a deficient design was obvious (72). In most cases the functional user tried to fulfill his responsibilities, but was hampered by the lack of experience in facility design and knowledge of manuals, regulations, codes and standards within the construction industry. His

standards were set by what he saw in his old shop and were not related to what was available in the construction industry.

Research Question #3. Some of the reasons why the functional user had not identified all special requirements in project books are discussed in the paragraphs above. In addition to those reasons the users of most facilities assumed the engineers are knowledgeable about their particular type of facility. For example, the user of a corrosion control facility, where aircraft are washed or painted daily, saw no need to include industrial type soap dispensers and paint stripping vats as special equipment (19). The user may not have the time required to do a thorough job in preparing inputs to the project book. Most facility managers interviewed in this research were not the managers who originated the requirement and provided input to the design process. AF assignment policies do not seem to encourage dedication to long-term projects.

Research Question #4. The reasons why all of the users' requirements were not satisfied fell into three categories.

1. First and most frequent was accidental oversight, or inexperience on the part of the design agent. The lack of definitive drawings, late design initiation or failure to follow a prudent design schedule contributed to deficiencies in the final design.

2. AF manuals, codes, or policies limited the type of materials, activities, or uses a particular facility design could accommodate.

3. The original cost estimate was too low to allow for inclusion of all required items, or a budgeting action reduced the amount of money available for a particular project.

Inexperienced project managers dependent on a staff of design specialists (organized in a horizontal hierarchy) are sometimes unable to provide the direction necessary to insure the facility users' requirements are satisfied.

Research Question #5. Functional deficiencies that impact the aircraft maintenance activities were easy to observe but hard to quantify. The impact ranged from the loss of a few seconds due to inefficient location of tools in a support section to temporary loss of use of an entire eight bay maintenance hangar due to incorrect design of aircraft entrance doors (48). The success of maintenance operations was measured in aircraft mission capable rates, sorties, and readiness. While mission capable rates and sorties are quantifiable, variation in rates are not necessarily correlated to deficiencies in facilities. Maintenance technicians learned long ago how to compensate for deficiencies. Longer work hours and counterproductive environmental conditions have become part of the aircraft maintainer's job description.

Research Question #6. Research has shown that some functional deficiencies keep recurring. As previously discussed, the designers of similar facilities are different; therefore, designs are treated as one-of-a-kind. It appears that the design agent (the COE) does not use a lessons-learned system to provide prints and specifications of previously designed facilities to the A-E firm selected for a particular project (29).

Research Question #7. The lack of definitive floorplans and specifications for facilities contributed to recurrence of deficiencies. If definitive specifications and single line drawings were not available, the design engineer and architect had to develop their idea of what the user needed. If the designers had not specialized in the type of facility under design, several iterations usually had to be presented to the user at design reviews. The COE normally scheduled a predesign review and two or three subsequent reviews. Most project managers allowed few major changes at the first design review (second meeting); after that time, users were told by the AF project manager that further changes would delay design efforts and cause the project to slip to the next fiscal year. Since the process was taking five years, few users would approve delaying the project. The statutory design fee limitation of six percent (of the programmed facility cost) provided little incentive for designers to invest additional time and effort in a

project once the minimum acceptable level had been reached (25).

Research Question #8. The most notable example of using lessons-learned from previous design and construction efforts is attributable to Air Force Logistics Command (AFLC). Standardized prints and specifications for construction of the engine hush house were developed by an A-E firm under contract to the AF. TAC attempted to provide a single line drawing of the floorplan for an AMU but met with limited success. HQ AAC assigned a staff officer to participate in all aircraft related facility design reviews for that command.

The corporate knowledge retained by the COEs was sometimes apparent during facility design reviews but was limited to generic type problems. TAC had hired an A-E firm to begin developing a standard alert facility. AFM 88-2 was no longer current, its standard facility drawings and specifications were of no use because they were outdated. However, the original objective of the manual, to provide approved definitive drawings which would expedite the construction programming process by eliminating the delays and errors created by the lack of firm design and requirements criteria is still valid.

Research Questions #9 and #10. Research questions 9 and 10 are closely related to the objective of this thesis and can be addressed together. The objective of this thesis

was to define a methodology to improve the functional utility of tactical aircraft maintenance facilities through improved design. The answers to research questions 9 and 10 are embodied in the methodology developed by the researcher.

A brief summary of that methodology follows with a detailed explanation presented in Chapter VI.

1. Select a facility type which frequently appears in the MCP.

2. Initiate a design project to optimize the functional utility of that facility and eliminate functional deficiencies.

3. Select an aircraft maintenance project officer.

4. Write a statement of work.

5. Use the COE as the design agent.

6. Hire an experienced A-E firm.

7. Encourage TAF participation.

8. Complete the design and distribute complete bid packages.

9. Establish a means of changing and updating prints and specifications.

Other Findings

The average time from project initiation to occupancy was four to five years. If a functional user established criteria for a MCP without knowledge of future changes in maintenance concepts, functional reorganizations, or major aircraft modifications, deficiencies in finished facilities

may result. For example, the conversion from conventional avionics to integrated avionics dictated a more open floor-plan in maintenance bays (16). Conversion from the four squadron maintenance concept to a three squadron concept (AFR 66-5) completely changed the size and responsibilities of the Organizational Maintenance Squadron (OMS) to those of the current Aircraft Generation Squadron (AGS) (21). The major deficiency in the current AMUs (lack of space) may be attributable to the old OMS organization.

The design schedule for some facilities at bases which experience harsh winters did not address the need to begin construction in the spring of the year. After design efforts reached 35 percent in September, schedule slips delayed award of three projects preventing construction start in the June timeframe. Loss of the June-October building season extends the facility completion date by one year. The functional users had to make do with substandard facilities or do without if no old facility existed (16; 19; 31).

Liability for deficient designs was an issue raised after occupancy of several maintenance facilities (1; 4; 48). The user had few options in these cases and little cooperation was received. If the difference between the actual facility cost and the funded amount were great enough, the user could ask the AF and the COE to issue a change order and correct the deficiency. This process was

much easier to describe than execute. In reality the correction of deficiencies was much more complicated. In most cases the user was unable to correct problems because neither the AF nor the COE was willing to sign change orders to correct deficiencies. Either bureaucratic drag or an unwillingness to admit mistakes seemed to be the cause. Whether the problem was a design deficiency or a requirement the functional user failed to identify, the result was essentially the same. If funds for the project were exhausted the user had no choice but to identify the deficiency, program corrective action, and wait. Attempted assignment of blame was wasted effort because the COE approved all designs submitted by A-E firms and approved shop drawings prepared by the contractors.

A representative of the functional user was invited to attend all facility design reviews. With the exception of the user, all attendees were usually engineers or architects. Normal procedure was to spend two days reviewing written design comments previously submitted. If the user's representative did not understand the terms used and the implications of decisions made by the engineers, or was unable to express his needs in terms understood by the attendees, his influence on facility design was minimal.

Time and motion studies were not included in this research effort. The researcher, however, routinely observed maintenance delays and work stoppages attributable

to facility deficiencies. Examples were as dramatic as work stoppages due to unsafe carbon monoxide levels caused by deficient ventilation or as mundane as an extra 60 seconds waiting for a tool (1; 7).

Summary

Several types of maintenance facilities, (AMUs, engine shops, and fuel shops), appeared frequently in the MCP. The projects were initiated by the functional users. Their responsibility was to provide criteria, specifications, and special requirements for inclusion in the project book. Few users realized the importance of their input and fewer still were able to provide the necessary information. Users perceived the engineers as the experts because the AF builds maintenance facilities every year.

However, similar facilities were not designed by the same A-E firms. Each project was treated as a one-of-a-kind facility and as a result, designs varied considerably. In attendance at over 30 design reviews, the same problems were being solved repeatedly. But, one would not expect a one-of-a-kind facility designed by engineers unfamiliar with its functional use to be free of deficiencies affecting functional efficiency.

The COE, which was normally the design and construction agent, did not use a lessons-learned system to improve the designs of like facilities. Maintenance facilities designed following the methodology identified by this research paper

should produce excellent results. Identification of functional deficiencies and discussion of research findings naturally led to several recommendations documented in Chapter VI.

VI. Conclusions and Recommendations

Introduction

This chapter presents conclusions and recommendations based upon the results of the research study. The chapter begins by presenting conclusions drawn from the findings which answered the research questions. Conclusions from additional findings follow.

Following the conclusions, several recommendations are presented which suggest ways this study could be used to improve the efficiency, and reduce the number of functional deficiencies in aircraft maintenance facilities. The recommendation suggests additional research which could be done based on the study.

Conclusions

1. Tactical AF units in the United States frequently design and build similar types of aircraft maintenance facilities. The AMU, Engine Shop, Fuel Shop, AGE Shop, and aircraft hangars were examples.

2. The functional users of most maintenance facilities were unaware of their responsibilities to establish criteria, specifications, and special requirements to be used in designing new facilities. Furthermore, the maintainers were not trained nor qualified to provide the detailed information engineers needed to design and

construct buildings devoid of deficiencies affecting the functional user.

3. Deficiencies in maintenance facilities occurred because of the following reasons:

a. Functional users failed to identify all requirements.

b. The original AF estimate used to program the facility was too low and the required scope of the project had to be reduced to stay within the programmed amount.

c. The design agent or A-E responsible for the design had never designed a similar type facility.

d. Most facilities were designed as one-of-a-kind without the benefit of lessons learned from construction of similar type facilities.

4. The impact of facility deficiencies was not quantified by this research. However, there was a negative impact on the efficiency of maintenance operations and the number of man-hours normally required to perform various tasks increased. Additionally, the cost to correct deficiencies listed in Appendix B would seem to be substantial.

5. If the methodology outlined in Chapter V were followed to develop definitive floorplans and specifications for frequently built maintenance facilities, functional deficiencies would most likely be reduced.

6. The facility requirements plans prepared by aircraft contractors provided a good basis for facility

design. However, the level of detail fell far short of that required for bidding documents.

General Recommendations

Senior logistics managers should adopt an initiative to develop definitive prints and specifications, of bidding document quality, for frequently built aircraft maintenance facilities. A sequential explanation of a methodology designed to promote the efficiency of maintenance operations and eliminate functional deficiencies follows:

1. Most types of maintenance facilities are similar in function and design from base-to-base. The functional user would benefit the most from improved design of those facilities which appear in the MCP frequently. Step one would begin when the proper logistics directorate initiates a project to produce standardized prints and specifications for a selected type of maintenance facility.

2. An aircraft maintenance officer experienced in facility use and design would be selected and appointed as the project officer. His charter would be to guide the process through the necessary steps while ensuring that lessons-learned from previous design attempts are incorporated. He would also be responsible for ensuring maintenance participation in the design and validation efforts. A project officer responsible for managing the design effort would also be appointed in the engineering directorate.

3. As with most facility projects, the initiating MAJCOM Engineering Directorate would be responsible for managing design effort. The COE would be the design agent for the project. COE participation in the project is essential because the success of the finished product depends on its acceptance by the COE.

4. A statement of work (SOW) would be written detailing the tasks to be accomplished and the expected results. This effort would require joint participation of the logistics and engineering staffs. The SOW would include the following:

a. Review of existing project files, and review of available criteria for that type facility would be mandatory. Research similar to that of this thesis would be required. Identifying means of correcting deficiencies documented through this process would be part of the design effort (see Appendix B). Coordination with logisticians and AFLC must be accomplished to plan for peculiar requirements of new weapons systems.

b. Site visits by the designers to five similar facilities recommended by the project officer would be mandatory. Functional users of those facilities would highlight the excellent features and discuss all deficiencies with the architects and engineers responsible for the design effort.

c. Three formal design reviews would be scheduled.

d. The finished product would be prints and specifications of bidding document quality with minimal requirements for site adaptation. Two foundation details would be provided--one for near frost-free environment and another for northern tier bases.

5. An A-E firm experienced in designing that type of facility would be selected. The logistics project officer would be included in the selection committee. The pre-design and follow-on design reviews would occur as detailed in step 4. Format and participation would be similar to that of a normal facility design review conducted by the COE. The A-E firm would be responsible for identifying scope limitations or design constraints imposed by AF publications which contribute to functional deficiencies. The logistics and engineering project officers would then be responsible for resolving those problems through normal channels.

6. Participation by tactical AF units in all appropriate commands would be encouraged. Time would be allocated for distribution of prints and specifications and return of comments from all interested MAJCOMs. Those interested parties would be invited to all design reviews. For certain types of facilities participation from ALCs may be appropriate.

7. Completed prints and specifications would be distributed to using MAJCOM maintenance and engineering

directorates. Use of the standardized bid package would be encouraged. Direction would be provided to the COE stating that only minor site adaptation would be required prior to completing construction of that type facility. However, variation from the design would be approved by the appropriate headquarters aircraft branch and engineering branches when required.

8. Standard drawings would allow the COE to do "in-house" site adaptation for future projects. Return on the funds spent for a standardized design would be realized through elimination of future full-scale duplicate design efforts.

9. A means of updating the package and making changes would be required. The initial SOW could include the requirement for the designer to provide this annual service.

10. Execution of this process would test its validity, its ability to reduce functional deficiencies, speed up the design process, and save construction dollars.

Recommendations for Future Research

Appendix B of this thesis is the beginning of a data base which could serve as lessons learned from the design and construction of maintenance facilities. More aircraft maintenance facility project files need to be researched and more maintenance facilities need to be observed to increase the size of the data base. If functional users cannot identify and document deficiencies or will not expend the

resources to do so, their experience will be wasted and their mistakes perpetuated.

Appendix B also provided recommended corrective actions for deficiencies identified. Further study of many of those recommendations is required.

Research indicates the functional users of maintenance facilities and the staff officer ranks have been somewhat remiss in their duty to establish definitive criteria for the aircraft maintenance work environment. As our fixed manpower resource is spread thinner to cover more weapons systems, means to improve operating efficiency must be exercised. The time has come to eliminate facility deficiencies which detract from efficient maintenance operations. The learning curve, expense, and lack of flexibility characteristic of one-of-a-kind design efforts can be avoided. The methodology defined in this thesis is the tool logisticians need to improve their facilities. Execution of that task is their responsibility.

Appendix A: Definitions

1. Definitive Drawings--Architectural prints of a proposed facility which specify room sizes, locations, electrical, and mechanical requirements.

2. Floorplans--Single line drawing showing the interior layout including room location and size.

3. Functional Deficencies--A defect in the design or construction of a facility which negatively impacts the ability of the user to accomplish maintenance operations. The deficiency detracts from the utility, efficiency, or flexibility of the finished facility.

4. Functional Requirements--Physical characteristics of a building which must be included in the design process to insure efficient and economical maintenance operations can be conducted.

5. Functional Specifications--Characteristics and qualitative desciptions of items required by the functional user to perform the type of maintenance intended in a given facility.

6. Functional User--The maintenance manager responsible for maintenance operations conducted within a given facility.

7. Hardened Facilities--Structural, electrical, and mechanical modifications to standard design made to protect a facility during attack.

8. Project Book--A document intended to completely describe the scope, functional requirements, and special provisions of a proposed facility. It is compiled by the AF and submitted to the COE who hire an A-E firm to proceed with the design of the facility.

9. Project File--A collection of all documents, and correspondence pertaining to a specific facility. The file contents usually cover the time period between project initiation and completion to include information concerning events which occur after the facility is occupied.

10. Scope--Includes the size (square footage), interior clear height, purpose, functions performed within, and special requirements of a maintenance facility.

11. Special Provisions--The equipment and capabilities the user wants but the facility designer does not know about.

12. Tactical Aircraft Maintenance Facility--A building constructed to house attack or fighter type aircraft for the purpose of performing maintenance. Also, building constructed to house shops maintaining aircraft parts.

Appendix B: Facility Deficiencies

Deficiency	PF	OBS	Problem Description	Problem Solution
Aircraft Maintenance Unit				
A--Facility Scope Insufficient	4/4	6/6	AFM 86-2 constrains the size of AMU facilities	Amend AFM 86-2 to allow 10,000 sq. ft. in TAF AMUs
A--Floor Coverings	1/4	6/6	Vinyl floor covering is not maintainable	Use terazzo tile
A--Completed Facilities	3/4	6/6	Self-help projects must be initiated to correct deficiencies	Standardize AMU design and benefit from lessons-learned
E--Computer Support	3/4	6/6	Many computers are required in an AMU, insufficient circuits available	Identify requirement and location for power and telephone circuits
A--Inappropriate Wall Coverings	1/4	6/6	Drywall did not meet appearance STD and was not maintainable	Use fire-rated wainscoat paneling with chairrail and vinyl paper

Key:
- A - Architectural
- E - Electrical
- C - Civil
- M - Mechanical
- S - Structural
- PF - Project File Reviewed
- OBS - Observed (Site Visit)
- #/# - The particular deficiency was mentioned in a certain number of facilities out of the number of project files reviewed or observed.
- #/# - The particular deficiency was observed in a certain number of facilities out of the number of facilities observed.

Deficiency	PF	OBS	Problem Description	Problem Solution
E--Radio Antennas Through Windows	0/4	3/6	No provisions made for routing of antenna cable	Define requirement and location for required antennas
A--Lack of Training	4/4	4/6	Some floorplans did not include room for training and testing	Provide required space in STD floorplan
A--OIC and NCOIC Not Co-Located	3/4	0/6	TAC STD floorplan separated the offices	Change STD floorplan, include room for assistant OIC
A--Poor Interior Design in AMU	2/4	6/6	Interior materials, colors and furnishings were not appropriate	Professional interior design using proven materials
C--Lack of Parking	4/4	6/6	Too narrow or too few POV spaces and no bicycle parking	Identify the requirement and design accordingly
A--Waste Disposal	2/4	4/6	No provisions for collection of waste lubricants or fuel	Design underground waste holding tanks for each-type of waste
A--Support Section Too Small	4/4	6/6	Portable buildings must be procured to store support equipment	Expand support section within the proposed 10,000 sq. ft.

Deficiency	PF	OBS	Problem Description	Problem Solution
A--No Space for Lockers	2/4	6/6	225 lockers are required to store personnel items and clothing	Allocate space for locker installation
A--Inefficient Clean-Up Area	0/4	6/6	Large numbers of technicians must clean up at the same time	Provide circular fountain type industrial sink to wash wash hands
C--Vehicle Access	1/4	5/6	Easy access to AMU is required for picking up equipment	Design easy to use drive by access to support section
A--Support Section Access	4/4	4/6	Mobility requirements dictate forklift and pallet access	Provide access and door in support section for STD pallet build-up
A--Lack of Space for Arctic Entry	2/4	2/6	Northern tier facilities require double door entry to keep cold out	Space allocated for arctic entry should not count in 10,000 sq. ft.
A--Support Section Door Design	0/4	6/6	High traffic doors fail to operate in facilities less than one year old	Use electrical sliding door with pressure sensitive matting
E--Number of Phone Jacks	2/4	4/6	Too few or improperly placed phone jacks limit office arrangements	Place plug for phones every ten feet on office walls

Deficiency	PF	OBS	Problem Description	Problem Solution
A--Window Hardware Broken	2/4	4/6	Cranks on windows and repiacement hardware is hard to get	Use sliding-type double-hung window without cranks
A--No Space for Technical Reps	2/4	5/6	No office space in AMU allocated for technical representatives	Provide space in 10,000 sq. ft. STD AMU
E--No Intercom System or Hotlines	2/4	6/6	Communication in AMU and with related functions is essential	Design appropriate intercom system and install required hotlines
A--Lack of Space for for Vending Machines	2/4	4/6	Not all floorplans included space dedicated for vending machines	Include dedicated space in 10,000 sq. ft. STD AMU
A--Lack of Space for Mobility Equipment	0/4	6/6	Most AMUs have mobility taskings but no space for equipment	Provide dedicated space in 10,000 sq. ft. AMU for mobility equipment
A--No Place for Flammable Storage	0/4	5/6	No area designated for flammable storage	Design space to meet applicable codes
A--Design of AMU Access Drive	0/4	3/6	Unpaved islands in AMU access drive increase amount of debris on pavement	Pave solid areas and use sloped shoulders
A--No Space for Turn-In Point	0/4	6/6	A repairable asset turn in/pickup area is required	Include suitable area in STD design

Deficiency	PF	OBS	Problem Description	Problem Solution
A--Lack of Sink and Counter Space	4/4	3/6	Counter space and sink are required in AMU dispatch area	Include in STD AMU design
A--No Classified Storage Vault	1/4	4/6	Each AMU requires classified storage space	Include in STD AMU design
A--No Function Layout of Floorplan	4/4	6/6	All AMUs had various problems with floorplans	Attempt to solve all identified problems with STD AMU design
A--No Storage for Lawn Maintenance Equipment	0/4	6/6	No storage place provided for lawn maintenance tools with outside access	Include in STD AMU design
A--Latrine Not Tiled	0/4	5/6	Wall coverings in latrines are hard to clean and not maintainable	Specify ceramic tile in latrines
A--Provisions Made for Handicapped	3/4	1/6	Handicapped equipment was included with no reason not required	Delete all handicapped provisions and save money
A--Lack of Emergency Lights	0/4	3/6	Emergency lighting was not specified in all areas required	Specify emergency lighting as required by codes
A--Space for Parts Shadow Board	0/4	4/6	AMU design omitted space for parts shadow board	Include in STD AMU design

Deficiency	PF	OBS	Problem Description	Problem Solution
Engine Shop				
A--Floorplans Not Optimal	6/6	2/3	Optimal floorplan and room sizes for similar functions not identified	Correct previously identified problem through STD design recommendations
M--Insufficient Ventilation	6/6	3/3	Ventilation in engine parts cleaning rooms do not meet standards	Design standard room with correct mechanical equipment
A--Unacceptable Floor Sealers	0/6	2/3	Deterioration of floor sealers and painted floors were common	Use light-reflective integral floor toppings on new floors
A--Engine Trailer Wash Rack	6/6	2/3	Wash rack not available or not equipped with pressure washer	Include wash rack in design with adequate mechanical equipment
M--Engine Parts Cleaning Equipment	6/6	3/3	Lack of definitive criteria cause significant design delays	Establish standard parts cleaning room equipment descriptions
A--Lack of Space in Support Section	4/6	3/3	Insufficient space for large numbers of tools and test equipment	Devise a better means of storage or increase size of support section
A--No Space for Bulk Storage	0/6	3/3	All shops have large items or mobility equipment to store	Provide space for bulk storage

Deficiency	PF	OBS	Problem Description	Problem Solution
Fuel Shop				
A--Lack of Wash Down Capability	0/4	2/2	Garden-type hoses had to be used for shop floor wash down	Provide hose bibs with industrial-type reels and proper flow volume
M--Shop Ventilation	3/4	2/2	Inadequate control of air temperature and insufficient air exchange	Design optimal system to move air and control temperature
M--Fuel Tank Ventilation	3/4	2/2	The temperature controls and the volume of air were deficient	Design optimal in-tank ventilation system
E--Electrical System Discrepancies	4/4	2/2	All equipment wiring and motors did not meet safety codes	Emphasize identification of all applicable codes during design
E--Grounding System	0/4	2/2	Static ground points in floor were not contiguous	Include this requirement in the design
A--Identification of All Criteria	4/4	2/2	Difficulty in finding and using all DOD and national codes	A-E firm must do necessary research and be experienced in fuel shop work
M--Treatment of Fuel Spills	2/4	2/2	A-E firm uncertain about how to handle fuel spills	Develop correct solution and standardize its application

Deficiency	PF	OBS	Problem Description	Problem Solution
Hush House				
S--Maintenance of Exhaust Tube	0/2	2/2	Movement of fixed liner panels causes frequent maintenance	Redesign panels to allow expansion and contraction
M--No Option to Install Heat Source	2/2	2/2	Northern tier bases need option to provide heat for technicians	Design option for radiant heat over work area
A--Administrative Space	2/2	2/2	No space was allocated for office, technical orders, latrine, etc.	Include adjacent administrative area in design
E--Refueling in Hush House Not Approved	2/2	2/2	Hush house design did not include provisions and analysis for in place refueling	Incorporate changes required in standardized prints and specifications
E--Door Tract Heating	2/2	1/2	Main entrance door heat trace would not work properly - ice accumulates	Correct design of heat trace and make it maintainable

Deficiency	PF	OBS	Problem Description	Problem Solution
Alert Shelter				
C--Compliance with Safety Criteria	0/2	2/2	World War II facilities were not in compliance with current explosive safety manuals	Ensure siting of new facilities allows for expansion
M--Inefficient Heating System	0/2	2/2	Hot air expelled from ducts near the roof promotes stratification	Duct hot air down to floor level
A--Outside Air Infiltration	0/2	2/2	Overhead one piece doors have poorly designed seals	Redesign seals to reduce air infiltration
E--Electrical Systems	0/2	2/2	Electrical wiring in hazardous areas does not meet code	Insure all codes and criteria manuals are used in design efforts
E--Static Grounds	0/2	2/2	Grounding points not located in proper places	Design static ground locations to accommodate all fighter aircraft
A--Lack of Space for Equipment	0/2	2/2	Aircraft maintenance hangar space was used for storage	Include required space for support equipment in floorplan
E--Emergency Lighting	0/2	2/2	No emergency lighting in aircraft cells	Include required lighting in design

Deficiency	PF	OBS	Problem Description	Problem Solution
E--Intrusion Detection	0/2	2/2	Security systems were not reliable	Install state-of-the-art alarm systems
A--Equipment Exhaust Infiltration	0/2	2/2	Exhaust from equipment running in cells infiltrated living area	Design living area in alert cells with a slight positive pressure
A--Foreign Object Accumulation	0/2	2/2	Expansion joints in floor of cells not properly caulked	Clean out joints and caulk properly
E--Cell Lighting	0/2	2/2	Cell lights had to be left on due to long start-up times	Design overhead lighting to include some incandescent fixtures
C--Cell Doors Freeze to Concrete	0/2	2/2	Accumulation of water under cell door freezes	Design gradient to prevent water accumulation under doors
A--Floor Sealers	0/2	2/2	Concrete sealer deteriorated and painted surfaces peeled	Use integral light reflective topping on new floors
A--Dining Area Too Small	0/2	2/2	Not enough room in dining area to accommodate workers	Size dining area to accommodate all those who normally work in facility

Deficiency	PF	OBS	Problem Description	Problem Solution
Aerospace Ground Equipment (AGE) Shop				
A--Floor Sealers	1/2	3/3	Floor sealers deteriorated and paint peeled	Specify integral light reflective non-metallic floor topping be used
M--Ventilation	1/2	2/3	Ventilation system did not remove carbon monoxide properly	Design ventilation system to handle normal industrial activity
M--Operation of Engine Run-Up Room	1/2	1/3	Engine exhaust system did not work properly	Redesign based on lessons-learned at Eielson AFB
A--Design of Engine Run-Up Room	1/2	1/3	Equipment viewing windows and cable access holes not included in design	Include required items in criteria for design of run-up room
M--Clean-Up Area	1/2	3/3	No industrial-type fountain sink or suitable area included in design	Specify necessary area and equipment required for personal hygiene
M--Monorail Hoists for Equipment	1/2	1/3	Number of hoists insufficient to support workload	Specify number and location of hoists required
C--Ice Covered Entry	0/2	1/3	Roof scupper positioned to allow drainage onto driveways	Locate scuppers and route drainage away from doors, driveways and windows

Deficiency	PF	OBS	Problem Description	Problem Solution
A--Equipment Storage Area	1/2	2/3	Not enough space allocated for AGE storage at northern tier base	Recognize AFM 86-2 criteria must accommodate cold weather storage
M--Overhead Doors	1/2	3/3	Garage-type door openers and hot air curtains not provided	Specify requirement in design criteria
A--Wash Rack Design	1/2	2/3	Equipment must be backed into wash area	Design drive-through wash area
M--Equipment Servicing	1/2	3/3	No mechanical means of servicing equipment was provided	Include servicing equipment requirement in design
M--Equipment Wash Area	1/2	3/3	No pressure washer or steam cleaner provided	Include mechanical cleaning equipment in design
A--No Provisions for Collection of Waste Lubricants	0/2	3/3	Waste lubricants and fuel had to be collected in 55 gallon drums	Provide segregated underground storage for waste lubricants and fuel
A--Location of Dispatch Office	1/2	2/3	Servicing area could not be seen from equipment dispatch office	Design floorplan accordingly
A--Refueling Area Drive Too Narrow	0/2	1/2	Unable to tow two AGE units through refueling area	Make drive-in refueling area wide enough for two units

Deficiency	PF	OBS	Problem Description	Problem Solution
<u>Hanger</u>				
A--Concrete Floor Sealer	4/4	4/4	Floor sealer deteriorates and provides no light reflectively	Specify integral light reflective floor topping for new floors
A--Expansion Joint Caulking	4/4	2/4	Debris accumulate in expansion joints due to concave caulking	Specify slightly convex caulking application as required
A--Design of Trench Drains	4/4	2/4	Trench drains connected between cells in hangar transport vapor	Specify drains in separate cells be isolated
A--Disposal of Waste Lubricants	3/4	1/4	Each hangar needs segregated waste disposal area	Provide separate underground tanks for collection of waste lubricants
M--Emergency Door Opener	4/4	3/4	Manual emergency door opener too slow to be effective	Specify acceptable criteria for door opener
M--Heat Circulation	4/4	3/4	Design allows hot air to stay at ceiling and cold air on floor	Duct hot air from heaters down to floor level
S--Design of One-Piece Doors	4/4	2/4	New overhead doors began to fail structurally	Redesign of door structure

Deficiency	PF	OBS	Problem Description	Problem Solution
M--Fire Detection System	4/4	1/4	Fire detection system for taxi through hangars not reliable	Redesign of system based on lessons-learned in other facilities
E--Hangar Lighting Intensity	4/4	0/4	Validity of IES standards uncertain	Develop agreed upon standard for light intensity and type
A--Roof Drainage Disposition	0/4	2/4	Drainage from hangar roof was deposited on aircraft taxi areas	Avoid drainage onto areas at northern tier bases
Miscellaneous Facilities				
M--Ventilation System	1/5	1/5	Inadequate ventilation in battery charging room	Design mechanical systems to meet industrial standards
M--Refrigeration Equipment	1/5	1/5	Household-type refrigerators were modified for battery storage	Include commercial refrigerators storage equipment in design
M--Method of Handling Batteries	1/5	1/5	Large tractor batteries were moved by hand	Install monorail hoist in proper location
A--Battery Pick-Up and Delivery	1/5	1/5	No efficient way to drop off or pick-up batteries existed	Design efficient system to exchange batteries

Deficiency	PF	OBS	Problem Description	Problem Solution
A--Materials in Charging Area	1/5	1/5	Walls and benches in battery charging area were not noncorrosive	Use noncorrosive-type material in required areas
M--Ventilation	1/5	0/5	Insufficient air exchange in aircraft painting area	Solve air flow problems through lessons-learned in other facilities
M--Design of Paint Booth	1/5	0/5	Designers were not knowledgeable concerning direction of air flow	Base design on lessons-learned in other facilities
M--Decontamination Design Criteria	1/5	0/5	Little information was available to guide design effort	Required research and lessons-learned must be documented
M--Functional Utility	1/5	0/5	Design agent lacked experience and exposure to accomplish task	Qualification procedures in AFR 88-31 should be followed
A--Design of Floorplan	1/5	0/5	No standard design for floorplan of integrated avionics shop	Develop standard design using methodology in this thesis
E--Inflexible Electrical System	1/5	0/5	Electrical power distribution design should be of generic design	Design system to support any type fighter

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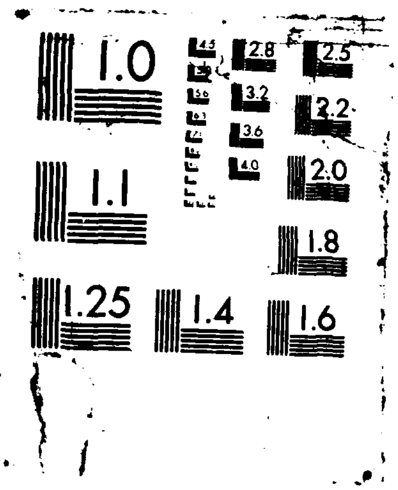
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Block 19. Abstract

This thesis was based on the hypothesis that functional deficencies in aircraft maintenance facilities could be reduced if definitive floorplans and functional specifications were available. The thesis examined deficiencies in tactical aircraft maintenance facilities which affected the functional users. Problems with the military construction program were explored through the programming, design and construction phases. Emphasis was placed on those defects which negatively impacted the functional users ability to efficiently carry out aircraft maintenance operations.

Research consisted of observing 25 maintenance facilities, reviewing 28 facility project files, attendance at 30 facility design reviews, and review of pertinent literature. Those types of maintenance facilities which appeared frequently in the MCP were selected for research.

The objective of this thesis was to define a methodology to improve the functional utility of tactical aircraft maintenance facilities through improved design. The process involved identification of deficiencies and recommendations for corrective actions.

Conclusions from this research indicated most maintenance facilities were designed as one-of-a-kind projects with little benefit from construction of similar type facilities. The same types of mistakes were often repeated, or previously successful aspects of completed facilities were designed differently due to lack of definitive floorplans, criteria, and specifications. The author recommended an initiative to develop definitive prints and specifications, of bidding document quality, for frequently built aircraft maintenance facilities. Additionally, a recommended methodology to accomplish this task successfully was developed and outlined by the author.

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